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Product Recovery From Hemlock "Pulpwood" From Alaska

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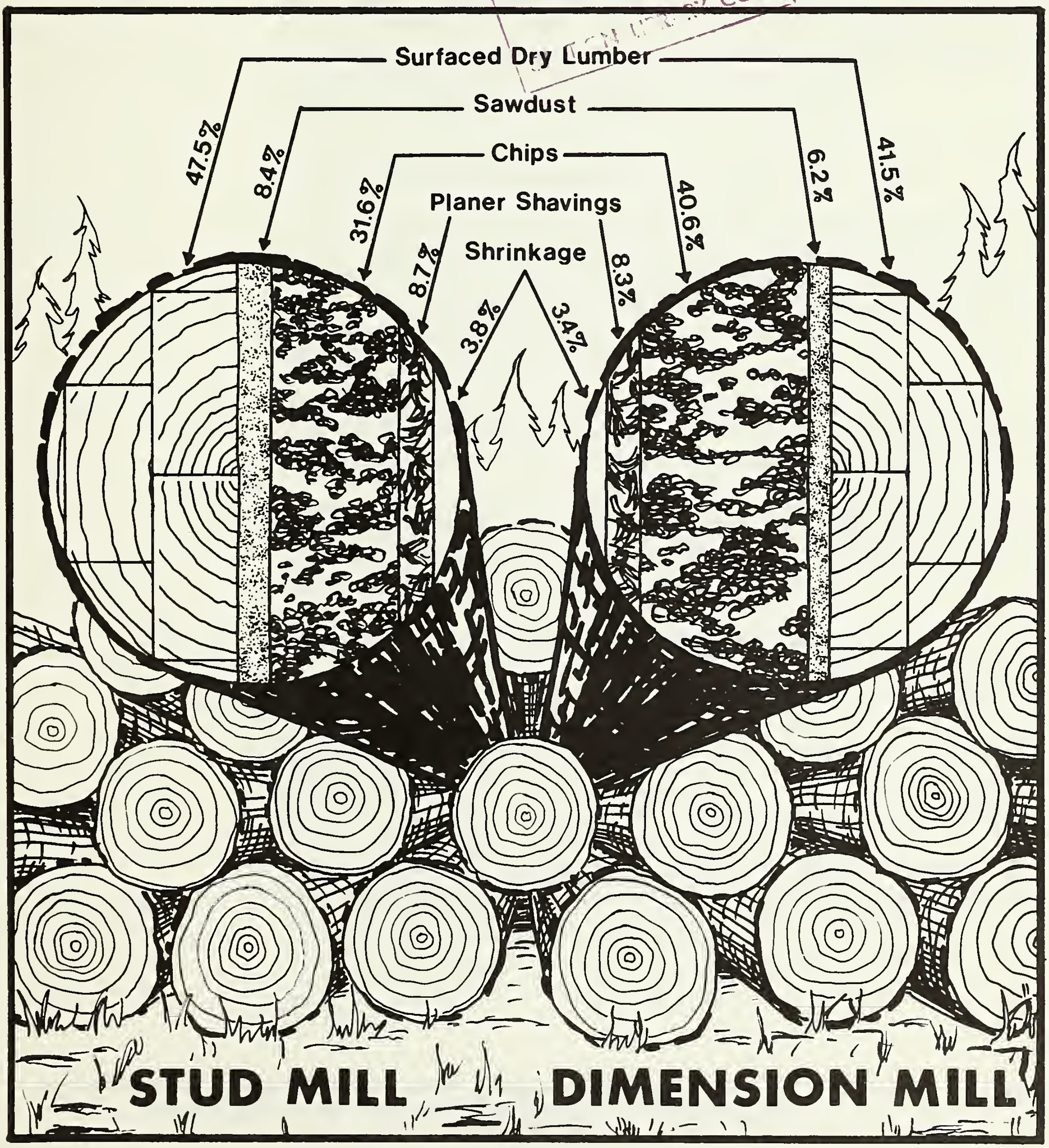

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Abstract

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A total of 363 western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) logs from Alaska were sawn to compare recovery at a stud mill and at a dimension mill. Recovery at both mills varied by log diameters and by log scaling system. Lumber grade recovery was primarily in Stud grade at the stud mill and in Standard and Construction grade at the dimension mill. Lumber volume recovery is based on long log Scribner scale and on cubic scale. Lumber recovery was 2.23 times the Scribner volume at the stud mill and 2.05 times the Scribner volume at the dimension mill. The lumber recovery factor was 9.0 at the stud mill and 7.5 at the dimension mill.

Keywords: Lumber yield, lumber recovery, lumber volume, log scaling, western hemlock, *Tsuga heterophylla*, pulpwood logs, dimension lumber, Alaska.

Summary

A group of western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) logs from Alaska cut as pulp logs were sawn into light framing lumber, 207 at a stud mill and 156 at a mill cutting random length dimension in the Pacific Northwest. Recovery at both mills varied by log diameters and by log scaling system. Recovery was different at the two mills mainly because of lumber grading and the differences in what the mills chose to chip or save as short or narrow lumber.

Lumber grade recovery was 95 percent Utility grade or better at the stud mill and 92 percent Utility or better at the dimension mill. Most volume was in the Stud grade at the stud mill and in Standard and Construction grade at the dimension mill.

Lumber volume recovery is based on long log Scribner scale and on cubic scale. Lumber recovery was 2.23 times the Scribner volume at the stud mill and 2.05 times the Scribner volume at the dimension mill. Lumber recovery factors were 9.0 at the stud mill and 7.5 at the dimension mill.

Average cubic volumes recovered per cubic foot of log volume were:

	Stud mill	Dimension mill
Surfaced-dry lumber	47.5	41.5
Shrinkage and shavings	12.5	11.7
Rough-green lumber	60.0	53.2
Sawdust	8.4	6.2
Chips	31.6	40.6

A method of predicting volume and value of both lumber and byproducts is presented that is suitable for use in stand evaluation, product allocation, and economic analysis.

Contents

Introduction

Western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) in southeast Alaska is not manufactured into the same products as in Oregon or in Washington or British Columbia. In Canada and the continental States, hemlock is used primarily for dimension lumber, but substantial volumes of both clears and "baby squares" are exported from mills on the coast. Pulp chips are the primary byproduct. In Alaska, logs larger than 15 inches scaling diameter are generally cut into export cants (Woodfin and Snellgrove 1976). Smaller logs are usually chipped for pulp. This condition is changing; currently, two new mills in Alaska are suitable for sawing small diameter logs.

The primary objective of this paper is to estimate the volume and value of light framing lumber and chips from small diameter hemlock logs from Alaska. A secondary objective is to compare volume and value of all products from a stud mill and a dimension mill. Precision end-trimmed (PET) studs and random length dimension are possible products for hemlock logs from Alaska.

Methods

Sample Selection

Logs were shipped from Prince of Wales Island in Alaska to the cooperating mills, where they were unloaded and rolled out for scaling. Logs for the study were selected on the basis of small end diameter. The sample had roughly equal numbers of logs in each diameter class from 5 through 14 inches. Logs were shipped from several logging camps and are considered representative of the range of "pulp" logs in Alaska. Sample size was 207 at the stud mill and 156 at the dimension mill. No log grade information was taken because all logs less than 12 inches in diameter would have been grade 3 because of diameter limits in the grading system. Based on surface characteristics, most of the logs would meet the grade 2 requirements.

Log Scaling

Scribner and cubic volumes of study logs were scaled by USDA Forest Service and industry check scalers. Long log Scribner scale was taken, using the Alaska interpretation of the Puget Sound Scaling Bureau Rules.[1] The Alaska rules vary on two points: (1) a 42-foot log is scaled as one piece instead of as two pieces, and (2) on split-scaled logs, a midpoint measurement is used rather than the standard taper allowance of 1 inch in 10 feet.

Cubic scale was taken in conformance with the cubic log scaling handbook.[2] Scale at the stud mill was compared among scalers, then reconciled by jointly remeasuring any logs about which the scalers disagreed. Scale at the dimension mill was not reconciled but was cross-checked against other scaling records and is considered accurate. The two scaling systems are different in both concept and application and are roughly defined as follows:

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[1] Official Log Scaling and Grading Rules. Puget Sound Log Scaling and Grading Bureau, Tacoma, Washington; January 1978.

[2] Cubic Scaling Handbook (review draft), National Cubic Measurement Committee, USDA Forest Service, Washington, D.C.; August 1978.

Scribner scale is the theoretical board-foot volume in 1-inch boards that can be recovered from a cylinder equal to the small end diameter of the log. Fractional inches are dropped, and deductions are made for defects thought to reduce the volume of merchantable lumber that can be produced from the log.

Cubic product scale (cubic scale) estimates the volume of fiber in the log from the diameter of both ends and log length. Fractional inches are rounded, and deductions are made for defects expected to reduce the volume of merchantable lumber.

Study Mills

Both mills used for the study were modern, efficient, well-run plants. Quality control and mill target sizes were in accord with the grading rules for the product line being produced. Both mills used continuous rising temperature (CRT) kiln schedules of about 72 hours.

Lumber was planed, then graded by certified company graders under the supervision of a West Coast Lumber Inspection Bureau (WCLIB) quality supervisor. All lumber was graded surfaced dry except: at the stud mill 2x2's and 1x4's were graded rough green; at the dimension mill 1x4's, 1x6's, and 2x3's were graded surfaced green. All lumber was tallied as shipped by the mill. Data were compiled by both surfaced-dry and actual rough-green lumber dimensions to provide an accounting of all cubic volume.

At both mills, logs were bucked to mill lengths and sawn to produce the mills' normal product line. Logs and boards were identified so that every board could be identified with the log from which it was cut. The dimension mill saved 1x4's, 1x6's, 2x3's, 2x4's, and 2x6's 6 feet and longer in even lengths only. At the stud mill items saved were 1x4's, 2x2's, 2x3's, 2x4's, and 2x6's, primarily PET 92-5/8 inches long; 6-foot-long 2x6's were also saved, as well as 2x4's in 4- and 5-foot lengths (finger-joint stock) and 6- and 7-foot and 88-5/8-inch PET Stud grade.

Product Prices

An index pricing system, which avoids the effect of market fluctuation and makes repricing easier, was used. A base price of $200 per thousand board feet (MBF) was picked for random length 2x4 and 2x6 of Standard or No. 2 and better grade. Prices for Stud, Utility, and Economy grades were developed using the average ratio of their prices to 4-inch-wide Standard and Better prices for the years 1976 to 1980 as supplied by Western Wood Products Association. The average ratio for this period was 93.5 percent for studs, so the indexed price per thousand board feet for studs is $200 x 0.935 or $187. Other prices were developed by the same general technique.

Prices used for the two mills were:

Dimension mill	$/MBF	Stud mill	$/MBF
Standard No. 2 and Better	200	PET Stud	187
1650f	200	1650f	187
Selects	325	Selects	325
Utility No. 3	126	Utility Stud	126
Economy	65	Economy Stud	65
2x3 Utility and Better	175	2x4 (4 to 7 ft) Stud	130
1-inch board Standard	175	1x4 mill run	76
1-inch board Utility	126	2x3 PET Stud	175
1-inch board Economy	65	2x2 mill run	116

Analysis of Data

The objectives of analysis were to: (1) determine suitable models for estimating product volume and value recovery and (2) compare recovery between the stud mill and the dimension mill. Linear and curvilinear models were used where appropriate.

Product recovery information has typically been assumed to vary with log diameter (Woodfin and Snellgrove 1976), but estimating recovery from log scale is easier and more direct (Fahey and others 1981). Both methods were used in this paper.

Research has shown that for most recovery by log diameter, a polynomial equation using the general term scaling diameter (D) and transformations D^2, $1/D$, and $1/D^2$—singly or in combination—best describes the relationship. Coefficient of determination (R^2) and F value were criteria for selecting the model. Where curvilinear models are displayed, regressions were run for D, $D+D^2$, $D+1/D$, $D+1/D^2$, and $D+1/D+1/D^2$, and the best fit was selected.

Lumber volume, lumber value, and chip volume were all assumed to have a linear relationship to log volume, so a linear model was used to compare mills.

Where results from the two mills are compared, analysis of covariance was used. Results were considered significantly different if the probability of the results occurring by chance were 0.05 or less ($p<0.05$). Results of analysis are discussed in the appropriate results section.

Results and Discussion

The results are presented in tables and figures. Recovery value is index priced so that it can be updated (see "Product Prices"). Results based on Scaling Bureau Scribner scale are applicable only in Alaska where this scaling system is used. Lumber grade recovery and the cubic volume information are applicable throughout the range of western hemlock.

Lumber Grade Recovery

The lumber grade recovery was typical of small diameter hemlock and fir (hem-fir) at west coast mills (Fahey and Hunt 1975), a very small volume of selects with most of it meeting the requirements of the dimension lumber grades.

In table 1 the 1650f visually stress-rated lumber is reported separately for information but is priced with Standard and Better or Studs (see "Product Prices") for the value section of this paper. Short studs 6 and 7 feet long are priced differently than PET studs. Finger-joint is 4- and 5-foot-long Stud grade lumber.

The biggest difference in lumber grade between the mills is in the percent of Utility grade lumber—4 percent at the stud mill and 28 percent at the dimension mill. This is related to both the lumber grading rules and board length. Stud grade allows a larger knot size than does Standard grade; a long board has a higher probability of having a grade-limiting knot than does an 8-foot stud. Some of the Stud grade lumber would have been Utility grade under the dimension grade rules if graded as 8-foot 2x4's.

The stud mill salvaged some items that were not saved at the dimension mill. Both 2x2's and short pieces less than 6 feet long were salvaged at the stud mill. This will affect the percentage of cubic volume recovered as lumber, sawdust, and chips and also the recovery percent.

Table 1—Total lumber production of hemlock logs from Alaska, by grade and size, for a stud mill and a dimension mill

Mill and lumber size	Selects	1650f	Stud[1]	Finger-joint	Construction No. 1	Standard No. 2	Utility and Better	Utility No. 3	Economy	Total
Inches					Percent					
Stud mill:										
1x4							2.25			2.25
2x2							3.27			3.27
2x3			5.44							5.44
2x4	2.09	13.76	57.39	3.28				4.36	5.06	85.94
2x6	.01		2.94	.04				.01	.10	3.10
Total	2.10	13.76	65.77	3.32			5.52	4.37	5.16	100.00
Dimension mill:										
1x4							2.28			2.28
1x6							2.24			2.24
2x3	.06	.02			0.39	0.35		.75	.39	1.96
2x4	1.29	4.21			12.90	23.10		20.32	5.72	67.54
2x6	.33	1.34			4.36	11.36		6.74	1.87	25.98
Total	1.67	5.57			17.65	34.81	4.52	27.79	7.98	100.00

[1]All 2x3's 92-5/8-inch PET Stud; 2x4's include 4.52 percent 6-foot Stud, 6.56 percent 7-foot Stud, 39.26 percent 92-5/8-inch PET Stud, and 7.13 percent 88-5/8-inch PET Stud; 2x6's include 0.67 percent 6-foot Stud and 2.27 percent 92-5/8-inch Stud.

Regression analysis was used to test for a linear correlation between lumber grade and log size at both mills. At the stud mill, the dependent variable was Stud grade plus 1650f as a percent of total lumber. There was no correlation between the lumber grade and log scaling diameter. The same test was run at the dimension mill using the Standard No. 2 and Better grade group as the dependent variable. Again, there was no correlation between log diameter and lumber grade. Lumber grade was not related to log diameter at either mill, so average lumber grade recovery can be used.

Recovery Percent Scribner Scale (Overrun)

Overrun is the recovery in lumber tally over and above net log scale expressed as a percentage of log scale:

$$\text{Overrun} = \frac{\text{Lumber tally - log scale}}{\text{Log scale}} \times 100.$$

Recovery percent is lumber tally divided by log scale:

$$\text{Recovery percent} = \frac{\text{Lumber tally}}{\text{Log scale}} \times 100.$$

A recovery percent of 200 would be equal to 100 percent overrun. Recovery percent is used throughout this report.

There is an apparent difference in average recovery between the two mills, 223 percent at the stud mill and 205 percent at the dimension mill. There is also considerable variation in recovery by diameter class for each mill (table 2). There is also a difference in "average" log volume between mills. Recovery varies by log diameter, so to test if the difference between the two mills is significant, recovery percent was plotted over diameter (fig. 1) and an analysis of covariance was used.

When recovery for the two mills was compared on the same diameter basis, recovery percent at the stud mill was 24 percent higher than at the dimension mill. This difference was not significant ($p<0.05$) for either slope or intercept because of the high variation around the recovery curves. The difference in intercept ($p<0.10$) was important enough that separate curves with the same slope are shown.

A 24-percent difference in recovery percent—although of practical importance—was not statistically detectable because the variation was so great, but both mills recovered more than double the scaled volume. Together, these facts indicate little relationship between the measurement system and what it is supposed to measure.

Lumber Recovery Factor

The lumber recovery factor (LRF)—board feet of lumber tally divided by cubic feet of log scale—varied between mills—9.0 at the stud mill and 7.5 at the dimension mill. It also varied with log diameter; individual factors for each mill and for each diameter class are in table 3, and the curved recovery by small-end diameter is in figure 2. Analysis of covariance showed that slope of the two lines was not significantly different, but the difference in intercept was significant at the 0.01-probability level. There was much less variation around the LRF lines than around the percent recovery based on Scribner scale.

Table 2—Recovery percent (overrun) of hemlock logs from Alaska, by long log Scribner scale

Scaling diameter	Stud mill: No. of logs	Log scale: Gross	Log scale: Net	Percent sound	Lumber tally	Recovery	Dimension mill: No. of logs	Log scale: Gross	Log scale: Net	Percent sound	Lumber tally	Recovery
Inches		Board feet	Board feet		Board feet	Percent		Board feet	Board feet		Board feet	Percent
4	4	100	100	100	499	499	--	--	--	--	--	--
5	20	510	470	92	1,348	287	9	260	260	100	604	232
6	24	1,010	890	88	2,664	299	20	970	920	95	2,033	221
7	14	780	750	96	1,786	238	17	800	720	90	17,886	248
8	25	1,760	1,610	91	4,669	290	25	1,940	1,810	93	3,953	218
9	18	1,400	1,280	91	3,336	261	16	1,130	970	86	2,108	217
10	15	2,720	2,470	91	5,387	218	15	1,590	1,770	90	3,390	213
11	21	3,440	3,230	94	7,080	219	15	1,750	1,600	91	3,467	217
12	25	5,220	4,620	89	9,987	216	17	2,850	2,530	89	4,995	197
13	17	4,150	3,980	96	7,967	200	12	2,620	2,260	86	4,576	207
14	21	5,760	5,440	94	10,888	200	8	1,960	1,760	90	2,753	156
15+	3	810	760	94	1,366	180	2	270	230	85	391	170
Total or average	207	27,660	25,600	93	56,977	223	156	16,320	14,650	90	30,056	205

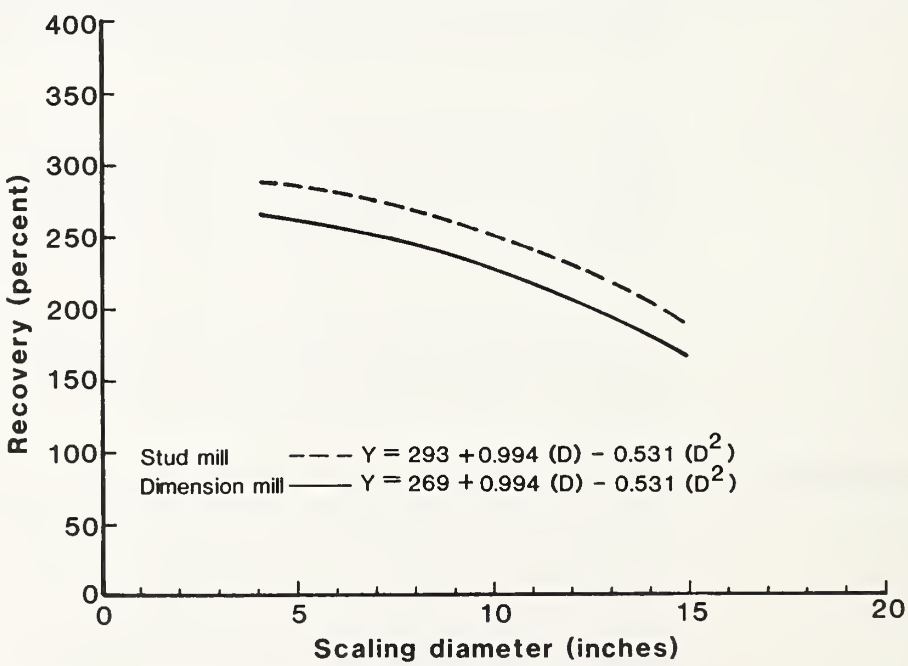

Figure 1.—Lumber recovery as a percent of net Scribner scale, by log scaling diameter.

Table 3—Cubic volume of products from hemlock logs from Alaska

Mill and diameter	Number of logs	Gross volume	Product volume	Lumber tally	Lumber recovery factor	Rough-green lumber	Surfaced-dry lumber	Sawdust	Chippable volume
Inches		- Cubic feet -		Board feet		- - - - - - Cubic feet - - - - - - -			
Stud mill:									
5	13	139.0	137.0	1,184	8.6	79.0	62.6	11.1	46.9
6	24	273.6	254.3	1,880	7.4	125.4	99.0	17.8	111.1
7	17	298.2	291.4	2,305	7.9	152.3	121.2	21.7	117.0
8	18	377.3	314.0	2,977	9.5	198.2	157.3	27.8	88.0
9	22	572.7	560.6	3,742	6.7	248.8	197.2	34.8	277.0
10	16	487.7	468.7	4,316	9.2	288.4	228.0	40.3	140.0
11	21	718.1	683.9	6,529	9.5	432.5	343.0	60.9	190.5
12	24	1,045.7	1,006.2	9,451	9.4	629.3	498.0	87.9	289.1
13	18	861.4	807.5	7,293	9.0	484.7	384.0	67.9	254.9
14	25	1,371.2	1,343.8	13,259	9.9	879.7	697.7	122.8	341.3
15	9	455.0	446.2	4,041	9.1	270.0	212.3	37.6	138.6
Total or average	207	6,559.9	6,313.6	56,977	9.0	3,788.7	3,000.3	530.5	1,994.4
Dimension mill:									
5	2	30.7	30.5	233	7.6	16.4	12.8	1.9	12.2
6	20	240.0	224.8	1,563	7.0	110.6	85.9	13.1	101.1
7	16	248.6	243.1	1,540	6.3	109.2	85.1	12.9	120.9
8	23	504.2	490.2	3,345	6.8	236.9	185.0	27.6	225.6
9	17	395.3	381.6	2,863	7.5	203.1	158.6	24.0	154.5
10	20	414.6	373.7	2,805	7.5	199.2	155.8	23.3	151.2
11	14	368.2	352.7	2,834	8.0	200.8	156.7	23.7	128.3
12	14	588.3	563.0	4,333	7.7	307.5	240.4	35.9	219.6
13	13	595.5	582.7	4,716	8.1	334.7	261.6	38.7	209.3
14	13	699.3	651.9	5,118	7.9	362.9	282.6	42.6	246.4
15+	4	138.7	113.8	706	6.2	501.	39.0	6.0	57.7
Total or average	156	4,223.4	4,008.0	30,056	7.5	2,131.4	1,664.5	249.7	1,626.9

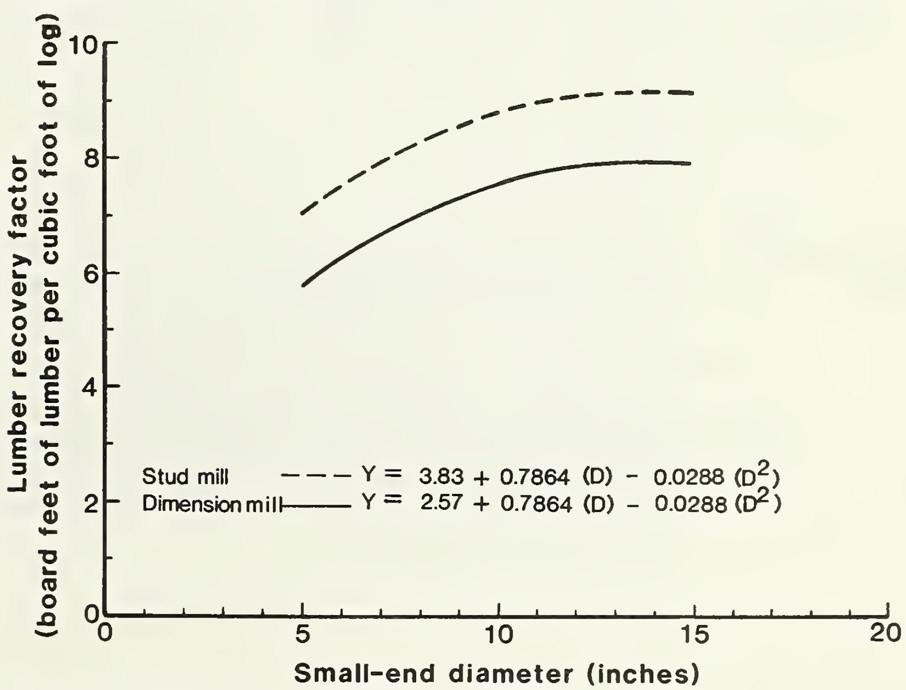

Figure 2.—Lumber recovery factor by small-end diameter.

Table 4—Cubic volume of lumber from hemlock logs from Alaska as a percent of cubic scale

Mill and diameter	Number of logs	Rough-green lumber	Surfaced-dry lumber	Shrinkage and shavings	Sawdust	Chippable volume
Inches		- - - - - - - - - - - - -	- - - - - - - - - - - - -	Percent	- - - - - - - - - - - - -	- - - - - - - - - - - - -
Stud mill:						
5	13	58	46	12	8	34
6	24	49	39	10	7	44
7	17	52	42	10	7	41
8	18	63	50	13	9	28
9	22	44	35	9	6	50
10	16	62	49	13	9	29
11	21	63	50	13	9	28
12	24	63	49	14	9	28
13	18	60	48	12	8	32
14	25	65	52	13	9	26
15	9	65	52	13	9	26
Total or average	207	60.0	47.5	12.5	8.4	31.6
Dimension mill:						
5	2	54	42	12	6	40
6	20	49	38	11	6	45
7	16	45	35	10	5	50
8	23	48	38	10	6	46
9	17	53	42	11	6	40
10	20	53	42	11	6	40
11	14	57	44	13	7	36
12	14	55	43	12	6	39
13	13	57	45	12	7	36
14	13	56	43	13	7	38
15+	4	38	29	9	5	58
Total or average	156	53.2	41.5	11.7	6.2	40.6

Cubic Volume of Logs and Products

Cubic volumes give the best estimates of recovery of all products. How much of the log was converted to rough-green lumber and ultimately to finished lumber? How much sawdust was generated and what volume of chips was sold?

The volume by component is in table 3, the percent of recovery by component by diameter class in table 4, and curved recovery by log diameter in figure 3. Covariance analysis was used to compare recovery of rough-green, surfaced-dry, and chippable volumes between the two mills. In all cases, analysis indicated that the slope of the curves was not different, but the intercepts were significantly different at the 1-percent level of probability.

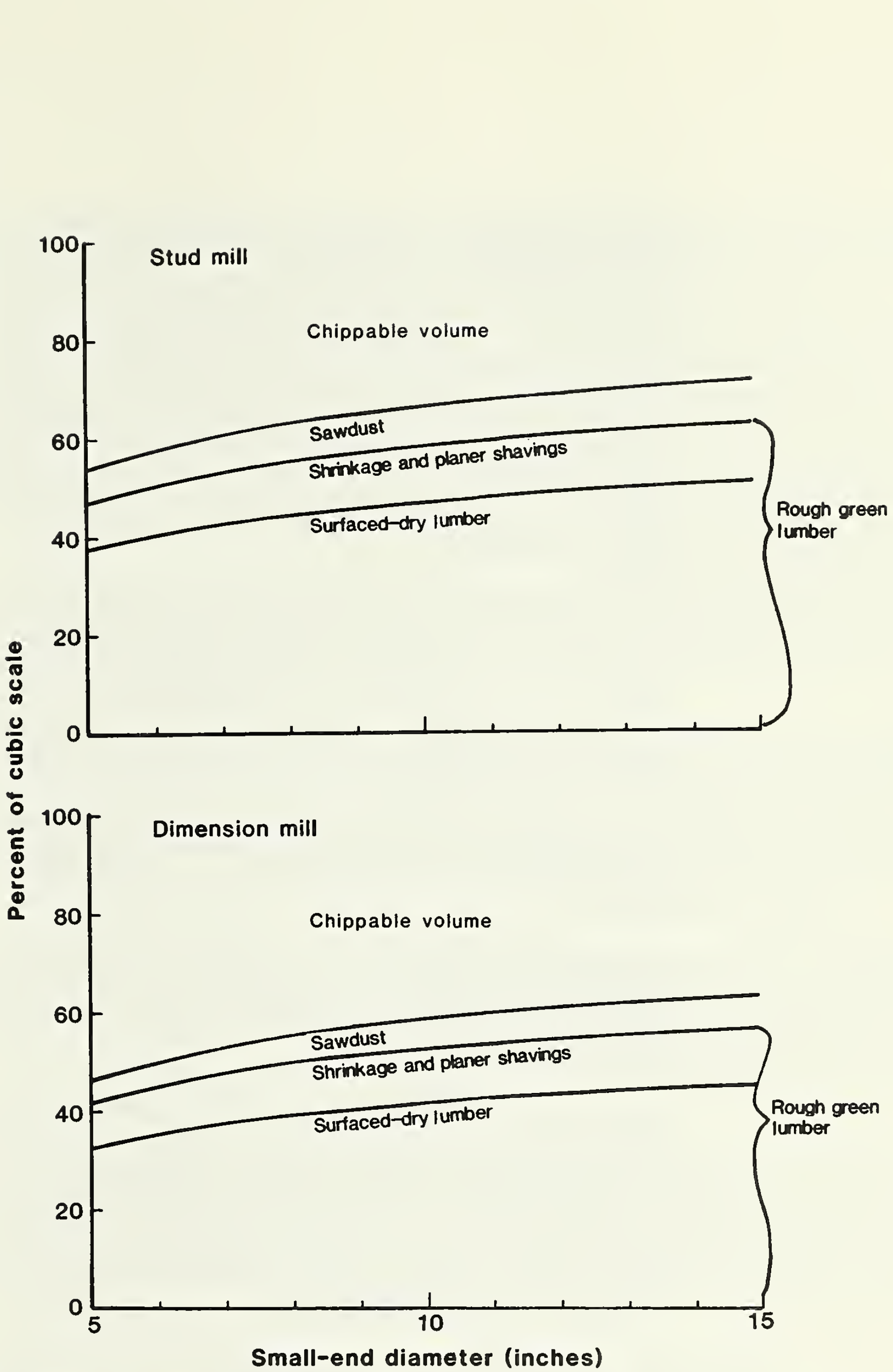

Figure 3.—Cumulative recovery and loss as a percent of cubic scale, by small-end diameter, for a stud mill and a dimension mill.
Stud mill: Rough green lumber and sawdust—$Y = 72.7 + 0.213(D) - 116.5/D$;
rough green lumber—$Y = 66.6 + 0.185(D) - 103.9/D$;
surfaced-dry lumber—$Y = 53.4 + 0.117(D) - 85.0/D$.
Dimension mill: Rough green lumber and sawdust—$Y = 68.6 + 0.213(D) - 116.5/D$;
rough green lumber—$Y = 61.4 + 0.185(D) - 103.9/D$;
surfaced-dry lumber—$Y = 48.6 + 0.117(D) - 85.0/D$.

The general averages in table 4 plus the lumber grade and items from table 1 are needed to explain the differences in volume between the two mills. The stud mill recovered 6.8 percent more of the log volume in rough-green lumber than did the dimension mill. Most of that gain was due to saving material that was not salvaged at the dimension mill. Recovery of 2x2's and finger-joint material accounts for 4 percent of the difference. Saving 7-foot and PET 88-5/8-inch studs from boards that would have been cut back to 6 feet at the dimension mill accounts for 1.6 percent. A very small portion, 0.2 percent, was due to difference in log diameter. The reason for the remaining 1 percent is unknown but is probably due to the sawyer's ability to select an efficient sawing pattern for each 8-foot segment rather than having to select a pattern for a longer log.

The stud mill used more of the log for planer shavings and shrinkage for two reasons: (1) it produced more lumber so it had to dry and plane more, and (2) it had more of the lumber in smaller items which have more surface to plane for every board foot produced. The actual allowance for planing was less at the stud mill because studs are allowed more planer skip than is allowed in Standard and Better dimension grades, and target sizes for rough-green lumber at each mill were set accordingly.

Sawdust volume was lower at the dimension mill because of less lumber produced, lower surface area per board foot, and a 0.140 saw kerf compared with a 0.160 kerf at the stud mill.

Less rough-green lumber and less sawdust resulted in more chippable volume at the dimension mill than at the stud mill. Both local markets and production costs for the individual mills need to be considered by each mill to determine whether to chip or saw the salvage items.

The cubic volumes recovered can be used to measure relative efficiency of the two mills. Both mills processing the study logs were efficient. Some differences in items saved exaggerate the slight advantage in efficiency that stud mills have over dimension mills. Saving 4- and 5-foot Stud grade and 2x2's plus the stud mill's ability to save 88-5/8-inch PET Stud and 7-foot Stud from material that would have been cut back to 6 feet at a dimension mill account for most of the difference in cubic volume of rough-green lumber recovered.

Besides the cubic volume of rough-green lumber, the other factor in determining LRF is board feet per cubic foot of lumber (Fahey and Woodfin 1976). Because the planer skip allowance for studs is greater than for Standard grade dimension, stud mills allow less for sawing variation and planing than do dimension mills. The approximate thickness of rough-green, 2-inch studs at the stud mill was 1.70 inches, whereas the thickness at the dimension mill was 1.74 inches. Board feet per cubic foot of lumber were 15.04 for the stud mill and 14.10 for the dimension mill.

Most of the differences between these two mills can be explained in terms of what lumber sizes mill management chose to save, and that studs can be cut smaller than dimension and still meet grading specifications.

Log Values

Log value is generally expressed in units of log measurement. Lumber grade and market price determine lumber value. This value is multiplied by the appropriate recovery percent or factor, and the result is either dollars per thousand board feet net Scribner log scale ($/MNLS) or dollars per hundred cubic feet product scale ($/CCF). These estimates have a total variation that cannot be quantified exactly because they combine several sources of variation. Biological variation in wood quality caused by either growth patterns or decay can affect both volume and value of wood recovered. Mechanical damage at the barker or mismanufacture in the sawmill or planer can have a negative effect on either volume or quality of lumber or both. Finally, the scaling system can introduce a great deal of variation. Both the method of computing gross volume and the method of deducting for defects affect variation. Both samples in this study were carefully scaled and manufactured with minimal breakage or mismanufacture so the error terms should be primarily biological variation and effect of scaling system. There was no correlation between lumber grade and diameter; therefore, variation in value should be primarily due to differences in lumber volume as a function of log volume.

Both $/MNLS (table 5) and $/CCF (table 6) are expected to vary with log diameter, and they did (figs. 4 and 5). Covariance analysis of $/MNLS showed that neither the slopes nor the intercepts were significantly different between the two mills. There was a $34 difference in source means that was not statistically significant because of the wide variation (fig. 4). Because of the size of the difference in intercepts, it is shown as two separate lines ($p<0.20$) despite the lack of statistical significance.

The $/CCF also varied by log diameter, scaling system being the only difference (fig. 5). Covariance analysis showed that the slope of the lines was not significantly different but that the intercepts were different at the 1-percent probability level. There was a difference of about $18/CCF between the lumber values at the two mills. This difference did not vary by log diameter.

Because these are the same logs with the same total values (only log scale differed), one method of estimating the value of lumber recovered from logs is more reliable than the other. To demonstrate which measurement system had the lower variation, the standard deviation (Sx) around the sample mean and the standard error of estimate (Sy·x) around the regression line were calculated as a percent of mean value using separate means and parallel regression lines:

Value	Scaling system	$Sx/\bar{x}$	$Sy{\cdot}x/\bar{x}$
$/MNLS	Net Scribner scale	54.5	53.6
$/CCF	Cubic scale	31.6	30.2

Cubic scale was, as expected, a better predictor of log value than was Scribner scale. This result conforms to results with white pine (Snellgrove and Cahill 1980).

Table 5—Average value of lumber from hemlock logs from Alaska, by long log Scribner scale

Mill and diameter	Number of logs	Scribner scale Gross	Scribner scale Net	Defect	Total value	Product
Inches		- Board feet - -		Percent	Dollars	$/MNLS[1]
Stud mill:						
4	4	100	100	0	79.88	799
5	20	510	470	8	212.89	453
6	24	1,101	8790	12	422.19	474
7	14	780	750	4	287.64	384
8	25	1,760	1,610	9	782.84	486
9	18	1,400	1,280	9	562.14	439
10	15	2,720	2,470	9	905.16	366
11	21	3,440	3,230	6	1,203.96	373
12	25	5,220	4,620	11	1,653.73	358
13	17	4,150	3,980	4	1,358.47	341
14	21	5,760	5,440	6	1,817.17	334
15	3	810	760	6	220.49	290
Total or average	207	37,660	25,600	7	9,506.56	371
Dimension mill:						
5	9	260	260	0	101.53	391
6	20	970	920	5	349.97	380
7	17	800	720	10	340.73	423
8	25	1,940	1,810	7	641.08	354
9	16	1,130	970	14	343.55	354
10	15	1,770	1,590	10	542.60	341
11	15	1,750	1,600	9	611.72	382
12	17	2,850	2,530	11	854.44	338
13	12	2,620	2,260	14	793.08	351
14	8	1,960	1,760	10	443.25	252
15+	2	270	230	15	73.95	322
Total or average	156	16,349	14,670	10	5,059.90	345

[1]/Dollars per thousand board feet, net Scribner log scale.

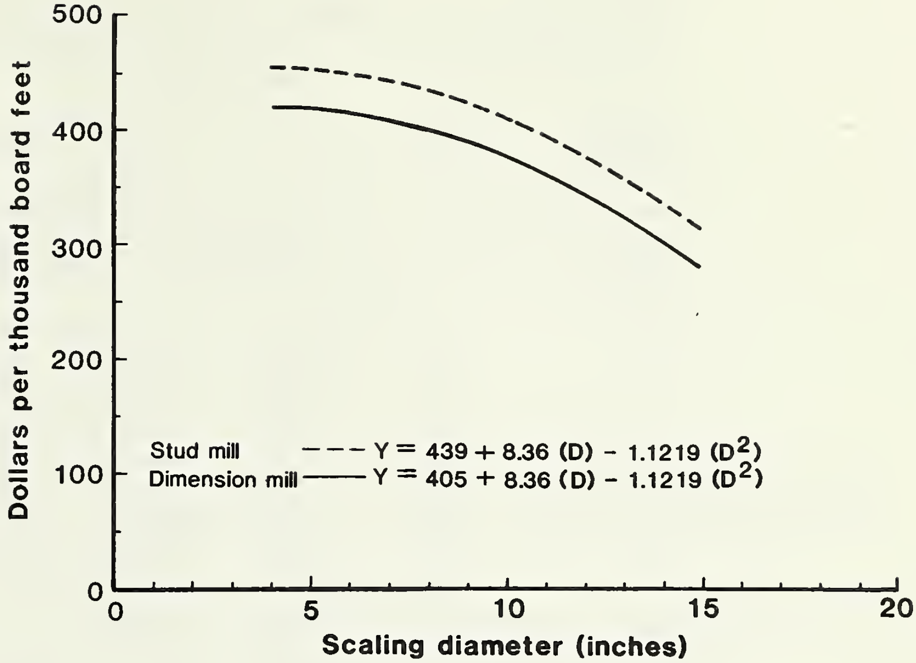

Figure 4.—Dollars per thousand board feet of logs, net Scribner scale, by scaling diameter.

Table 6—Average value of lumber from hemlock logs from Alaska, by cubic scale

Mill and diameter	Number of logs	Cubic scale: Gross	Cubic scale: Net	Defect	Total value	Product
Inches		- Cubic feet - -		Percent	Dollars	$/CCF[1]
Stud mill:						
5	13	139.0	137.0	2	189.58	138
6	24	273.6	254.3	7	291.75	115
7	17	298.2	291.4	2	371.19	127
8	18	337.3	314.0	7	496.87	158
9	22	572.7	560.6	2	626.68	112
10	16	487.7	468.7	4	708.87	151
11	21	718.1	6783.9	5	1,125.18	165
12	24	1,045.7	1,006.2	4	1,587.44	158
13	18	861.4	807.5	6	1,199.22	149
14	25	1,371.2	1,343.8	2	2,236.95	166
15	9	455.0	446.2	2	672.83	151
Total or average	207	6,559.9	6,313.6	4	9,506.56	151
Dimension mill:						
5	2	30.7	30.5	1	41.67	247
6	20	240.0	224.8	6	269.40	120
7	16	248.6	243.1	2	256.39	105
8	23	504.2	790.2	3	547.69	112
9	17	395.3	381.6	3	469.52	123
10	20	414.6	373.7	10	461.60	124
11	14	368.2	352.7	4	461.15	131
12	14	588.3	563.0	4	743.66	132
13	13	595.5	582.7	2	825.01	142
14	13	699.3	751.9	7	862.97	132
15+	4	138.7	113.8	17	120.84	107
Total or average	156	4,223.4	4,008.0	5	5,059.90	126

[1] Dollars per hundred cubic feet.

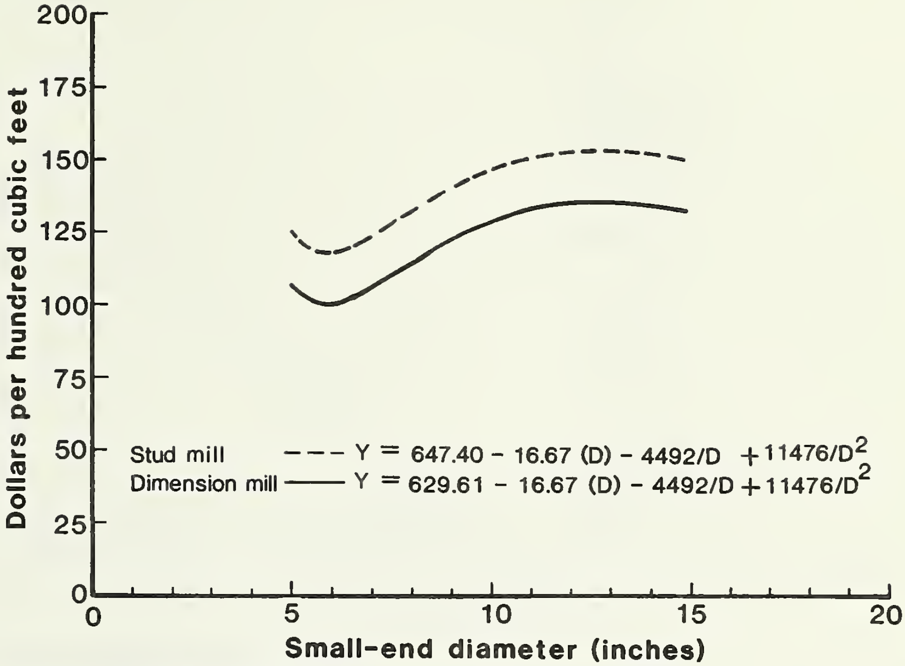

Figure 5.—Dollars per hundred cubic feet of logs, by small-end diameter.

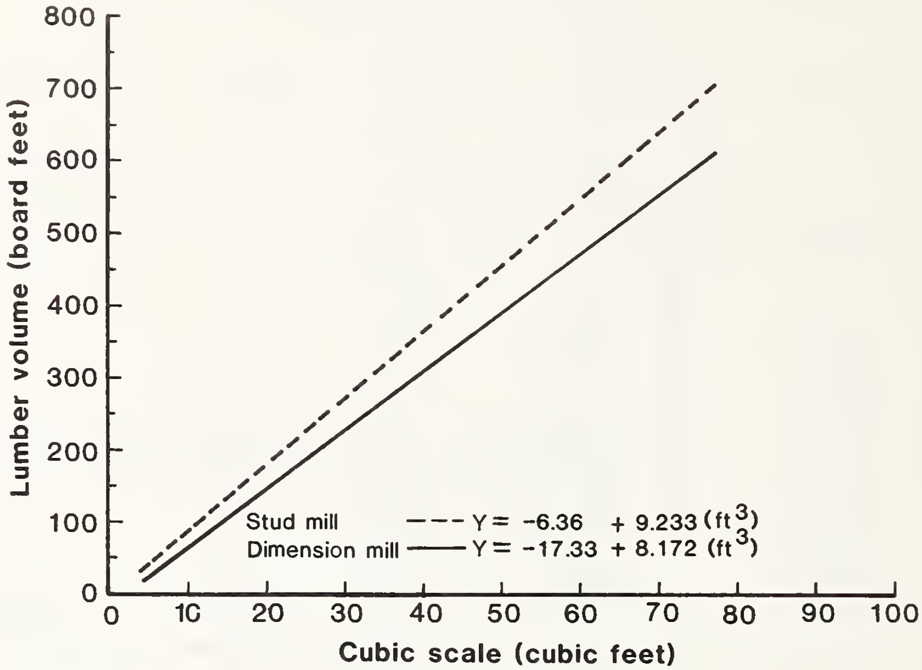

Figure 6.—Total lumber volume in board feet, by log cubic scale.

Direct Product Estimators

Product volume and value can be predicted directly from log scale (Fahey and others 1981). Cubic scale was used because it is much less variable than Scribner scale. The same type of estimate can be made for Scribner scale but at a considerable loss in precision.

Total lumber tally from a log is directly related to the cubic volume of the log. Total value of lumber and volume of chippable fiber are also correlated with log volume. The relationship between lumber tally and cubic log scale is shown in figure 6. The coefficient of determination (r^2) between cubic scale and lumber tally is 0.85 at the stud mill and 0.93 at the dimension mill. The slopes of the two lines are significantly different at the 1-percent probability level.

Lumber value is also directly correlated to cubic scale (fig. 7). Calculated r^2 is 0.82 at the stud mill and 0.89 at the dimension mill. The slopes of the two lines are different at the 1-percent probability level.

Volume of chippable wood can also be estimated from log cubic volume (fig. 8); r^2 is 0.51 at the stud mill and 0.80 at the dimension mill. Slopes are different at the 1-percent probability level. Use of these figures will be discussed in "Application."

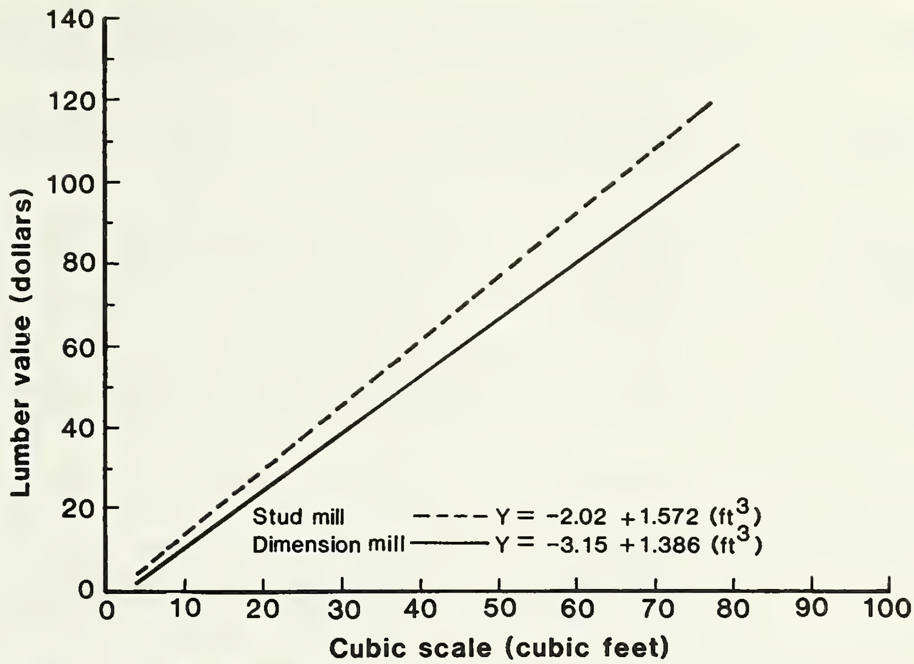

Figure 7.—Total lumber value by log cubic scale.

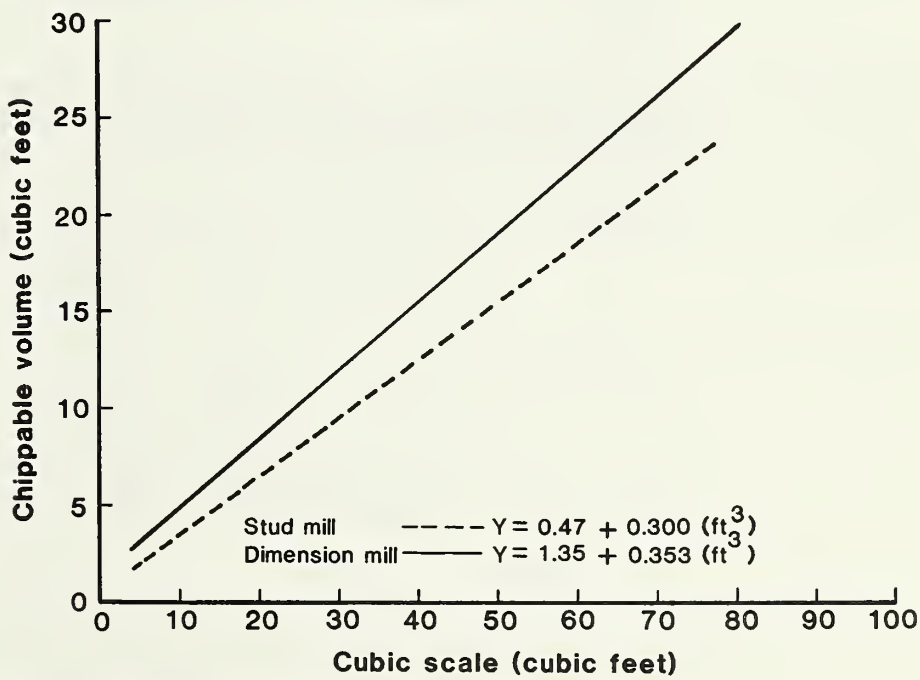

Figure 8.—Chippable volume by log cubic scale.

Application

From the information in figures 6, 7, and 8 and the stud mill as an example, the volume and value of lumber and chips can be estimated directly for any log.

For a log containing 10 cubic feet (CF), volume or value is estimated from the equations that describe the relationships in figures 6, 7, and 8. For example:

Lumber tally = -6.36 + (9.233 x 10 CF) = 86 BF (board feet).
Lumber value = -2.02 + (1.572 x 10 CF) = $13.70.
Chippable volume = 0.47 + (0.300 x 10 CF) = 3.47 CF.

If a chip price of $80 per oven-dry ton or $0.04 per pound is assumed and 24 pounds per cubic foot on an oven-dry weight per green volume basis (Wangaard 1950) is used, there are 83 pounds of chippable fiber with a value of $3.33; total value = $17.03.

At the dimension mill, the results would be a little different:

Lumber tally = -17.33 + (8.172 x 10 CF) = 64 BF.
Lumber value = -3.15 + (1.386 x 10 CF) = $11.71.
Chippable volume = 1.35 + (0.353 x 10 CF) = 4.88 CF
= 117 lb at $0.04 = $4.68; total value = $16.39.

This does not include direct manufacturing costs, which would be higher at the stud mill because of processing and saving the smaller lumber items such as 2x2's and finger-joint.

If this procedure works for one log, it will work for a group of logs. As an example, take a group of small logs where 120 logs equal 1,000 cubic feet (MCF), and a group of larger logs where 20 logs equal 1,000 cubic feet.

Total lumber at the stud mill for each group would be:

-6.36 (120) + 9.233 (1000) = 8,470 BF;
-6.36 (20) + 9.233 (1000) = 9,106 BF.

Lumber value = -2.02 (120) + 1.572 (1000) = $1,330;
-2.02 (20) + 1.572 (1000) = $1,530.

Chip volume = 0.47 (120) + 0.300 (1000) = 356 CF = $342;
0.47 (20) + 0.300 (1000) = 309 CF = $297.

From the estimates of lumber value, total value, total lumber tally, and log scale, calculate $/MLT or LRF:

Logs/MCF	Large logs (20/MCF)	Small logs (120/MCF)
(1) Total lumber tally, BF	9,106.00	8,470.00
(2) Total lumber value, dollars	1,530.00	1,330.00
(3) Total log scale, CF	1,000.00	1,000.00
(4) Total value including chips, dollars	1,827.00	1,672.00
$/MBF lumber tally (2)/(1)x1,000	168.00	157.00
$/CCF (4)/(3)x100	182.70	167.20
LRF (1)/(3)	9.106	8.470

For the larger logs, the average $/MBF increased. Although percentage by lumber grades did not vary with log size (diameter), a higher percentage of the lumber is recovered in the high value PET lengths and less in the salvage items, such as short studs and 2x2's.

Because the lumber is index priced, it is relatively easy to update prices to current levels; calculate total lumber value first, then adjust by the ratio of current price of PET Stud to the $187 price used for PET Stud.

Other adjustments are possible and only slightly more difficult. The 8-foot rough-green 1x4 is of marginal value as is indicated by its $76/MBF selling price. If the mill chose to chip this item, lumber, volume of chips, and value would all change. In table 1, about 2.3 percent of the lumber volume was in 1x4 mill run. The result of chipping this would be a 2.3-percent decline in lumber tally. Lumber value would decline about 1 percent. This can be calculated several ways. Volume and value of chips would increase by 2.3 percent x (rough-green recovery percent from table 4) x log volume.

It is now possible to rework the example for 120 logs and 1,000 cubic feet from the stud mill.

From the earlier example, volume and value are:

	Volume	Value
Lumber	8,470 BF	$1,330
Chippable volume	356 CF	$342

Adjusting lumber tally is easy:

8,470 x 97.7% = 8,275 BF.

Adjusting lumber value is slightly more complex:

Either -2.3% x 76/157 = -1.113% of value so $1,330 x 0.9887 = $1,315,
or 195 BF x $76/1,000 = $15. So $1,330 - $15 = $1,315,
and finally, 2.3% x 60% (cubic recovery percent of rough-green lumber) x 1,000 CF = 14 CF of additional cubic volume to chips.
Adjusted chip volume is 370 CF or $355.

The effect on value can be displayed as follows:

	Lumber	Lumber value	Chip volume	Chip value	Total value
	(Board feet)	(Dollars)	(Cubic feet)	(Dollars)	(Dollars)
With 1x4	8,470	1,330	356	342	1,672
Without 1x4	8,275	1,315	370	355	1,670

At these prices, there is little or no advantage to producing the low valued lumber.

Conclusions

One major conclusion can be drawn from the study; it is possible to produce dimension lumber from western hemlock pulp logs in Alaska. The recovery reported here would not be attained in Alaska. Most of the Economy grade at the dimension mill or lower grade and salvage items at the stud mill would be chipped in Alaska because of a lack of local markets.

Relative mill efficiency (board feet per cubic foot of lumber) would probably be lower in Alaska. Equipment to assemble a mill to achieve this level of efficiency can be bought from any of several suppliers. The highly skilled millwrights, sawfilers, electricians, and supervisors necessary to maintain this level are generally assembled and trained over long periods. Finally, high recovery sawing does cut volume production slightly and is most common where the cost of logs is very high relative to other production costs.

Cubic scaling was much more closely related to product recovery than was Scribner board-foot scaling. This agrees with past comparisons of long log Scribner scale with log cubic volumes. Cubic scale is an estimate of the cubic volume capable of producing lumber and appears to be an effective estimator of volume and value of lumber and of byproducts.

Metric Equivalents

1 inch = 2.54 centimeters
1 foot = 0.3048 meter
1 cubic foot = 0.02832 cubic meter

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A total of 363 western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) logs from Alaska were sawn to compare recovery at a stud mill and at a dimension mill. Recovery at both mills varied by log diameters and by log scaling system. Lumber grade recovery was primarily in Stud grade at the stud mill and in Standard and Construction grade at the dimension mill. Lumber volume recovery is based on long log Scribner scale and on cubic scale. Lumber recovery was 2.23 times the Scribner volume at the stud mill and 2.05 times the Scribner volume at the dimension mill. The lumber recovery factor was 9.0 at the stud mill and 7.5 at the dimension mill.

Keywords: Lumber yield, lumber recovery, lumber volume, log scaling, western hemlock, *Tsuga heterophylla*, pulpwood logs, dimension lumber, Alaska.

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